# THE IR DETECTOR SYSTEM FOR THE GERB INSTRUMENT

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## ABSTRACT

The Geostationary Earth Radiation Budget (GERB) instrument is an Earth observing scientific payload launched on-board the European Space Agency Meteosat Second Generation (MSG) satellite in September 2002. The instrument measures reflected and emitted radiation in two wavebands, 0.3 – 4 μm and 4 – 30 μm. The detector system comprises the focal plane and supporting front-end electronics. The focal plane consists of a 256-element thermoelectric linear array operating at ~300 K and four application specific integrated circuits (ASIC) providing parallel amplification, filtering and digitisation. The front-end electronics are built around a digital signal processor, which performs integration and additional filtering of the ASIC product. This paper describes in detail the design, operation and performance of the GERB detector system.

## INTRODUCTION

The aim of the GERB instrument[1] is to monitor the total radiation output (reflected and generated) from the Earth in the 0.3 to 30 μm range, over a period of several years, providing data for climate modelling and inter-calibration with other instruments. The MSG satellite will be placed into geostationary orbit at 0° latitude, 0° longitude (it is currently in a commissioning orbit at 0° lat, 10°W lon) from where GERB will view the whole Earth. The satellite rotates at 100 rpm and, to compensate for this, the instrument uses a de-spin mirror to stabilise the Earth view onto the detector for a period of ~40 ms, once per revolution of the spacecraft. During this time, the linear detector sees a complete slice of the whole Earth view in the North-South direction. Also, during each revolution, for calibration purposes, the detector views an internal warm blackbody and a solar diffuser. The motion of the de-spin mirror is adjusted during subsequent satellite rotations to scan the detector view forwards and backwards and in this way a full image of the Earth is obtained every 5 minutes.

## DETECTOR SYSTEM DESCRIPTION

### Overview

The detector system is divided into two parts, the focal plane assembly (FPA) and the associated front end electronics (FEE). Both units are contained within the instrument optical unit and are connected by a 0.75 m cable. Figure 1 is a simplified schematic of the detector system.

### Focal Plane Assembly

The FPA components include detector, ASICs (4 off) and support electronics (voltage reference, decoupling and connector). Each of these sub-circuits is mounted on gold-plated ceramic circuit boards that include test structures. In addition the detector is mounted on a silicon substrate providing connection fan-out before mounting on the ceramic circuit board. Once operation of the sub-circuit is confirmed the test structures are removed. The individual sub-circuits are then mounted onto a molybdenum backplate and wire bonded together (figure 2). An aluminium plate covers the whole assembly with a single aperture for the detector.

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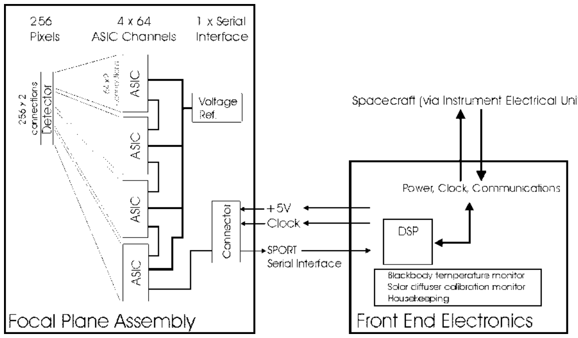



***Figure 1:*** *GERB detector system schematic.*

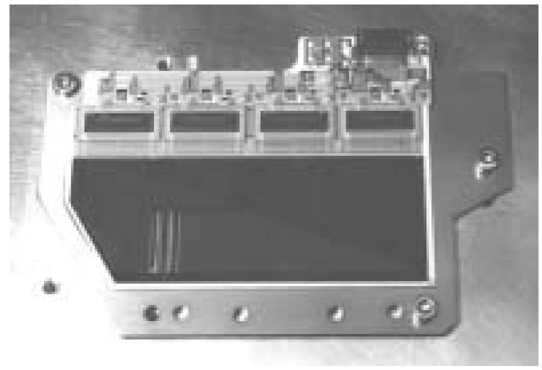


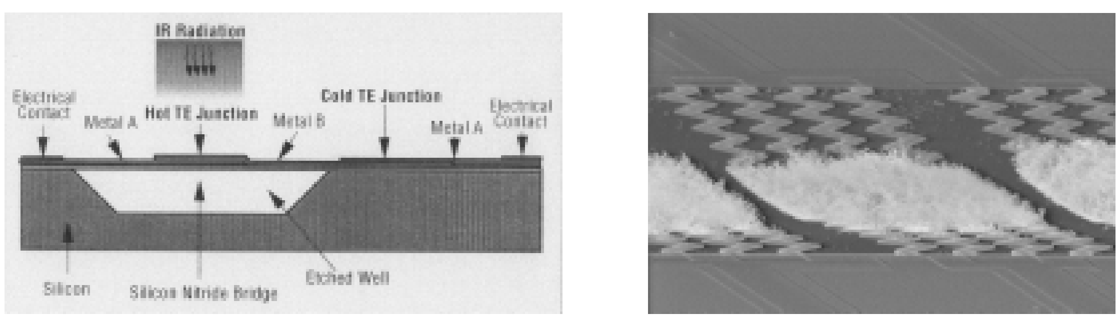
***Figure 2:*** *GERB focal plane assembly.*

**Detector**

The detector is a custom thermoelectric linear array manufactured by Honeywell. It is a silicon micro-machined structure (figure 3a) with 256 pixels. Detector parameters are listed in table 1. The detector pixels also have a reticulated 20 μm thick goldblack coating (99% Au, 1% Cu) (figure 3b) to improve spectral response.

***Table 1:*** *Detector parameters*

| | |
|---|---|
| Number of pixels | 256 |
| Pixel size | 45 μm x 55 μm |
| Pixel pitch | 55 μm |
| Fill factor | 82% |
| Impedance | ~1200 Ω |
| Responsivity | 300 V/W |
| Time constant | ~4 ms |
| Noise source | Johnson noise of resistance |




*a)* *b)*

***Figure 3:*** *a) Pixel structure schematic and b) SEM micrograph of a single detector pixel showing goldblack coating.*

**ASICs**

Each GERB ASIC[2] has 64 parallel signal processing channels allowing the full detector to be serviced using four devices. The ASIC is manufactured using the Mietec 0.7 μm CMOS process. Each channel comprises an input amplifier and a sigma-delta modulator to perform digitisation. To reduce the effect of 1/f noise introduced by the use of the CMOS process the input amplifier is chopped and then followed by a demodulator to return the signal to DC. This scheme has the disadvantage that the signal is sampled only for half the integration time whilst the noise is sampled over the whole period. To avoid this situation the amplifier input is chopped between the positive and negative outputs from a detector pixel, necessitating a differential connection. The output of the sigma-delta modulator feeds into a decimation filter to reduce the data rate and outputs from the 64 decimated channels are shifted into a serial register for data output. The shift register also has a serial data input allowing up to four devices to be cascaded and is compatible with the SPORT interface of the Analog Devices ADSP21xx series of digital signal processors (DSP).

Timing is controlled by an external clock (in the case of GERB it uses the spacecraft clock at $2^{25}/9$ Hz ~3.73 MHz). The sigma-delta ADCs run at 1/64 of this rate. Two decimate by 128 filters operate in parallel, 180° out of phase and produce a new sample every 64 ADC clock cycles. The filters are shared by all 64 channels and hence are 64 times over-clocked. The maximum filter output is $64^2 = 4096$, which is represented as a 12-bit number (The ADC will not produce an all '1's data stream so the actual maximum is 4095). Frame count and parity bits are added to each sample, which is then fed into the serial register as a 16-bit word. The serial register is clocked continuously at the external clock rate which means that the entire 64 x 16 bits is shifted out in 1/4 of the output sample rate, in-line with the ability to cascade up to four ASICs. Operation from the GERB spacecraft clock results in a parallel (256 channels) sample time of 1.098 ms. The ASIC has an input signal range of ±125 μV and a dynamic range of >1600. It operates from a single 5 V supply and dissipates 150 mW.

## Front End Electronics

The FEE is built around an Analog Devices ADSP-2111 DSP which allows direct connection of the FPA (ASIC) serial output to the SPORT interface. The stable viewing period of the detector (Earth, blackbody or solar diffuser) is 40 ms (as determined by the rotation of the spacecraft and the de-scan mirror mechanism). The purpose of the FEE is to digitally integrate and process the output from the FPA during the 40 ms observation time. 36 samples are taken during this time (36 x 1.098 ~ 39.5 ms) which are then convoluted with a filter optimised for the pixel time constant. A second filter provides a correction term for any changes in time constant during operation. The filtering provides high-frequency noise reduction and removal of detector memory effects, essential for an integration time of order only ten pixel time constants.

The FEE also monitors the warm blackbody temperature, solar diffuser calibration diodes and housekeeping parameters.

## DETECTOR SYSTEM PERFORMANCE

Detector parameters evaluated include time constant, noise, linearity and spectral response. The time constant of each pixel was measured and the results are shown in figure 4. Linearity was measured using an Ar-Ion laser at a wavelength of 514 nm and the detector output normalised to a standard reference detector. Figure 5 shows the average linearity of the central 50 detector pixels. The error bars indicate the range within which 2-sigma of the pixels fall.

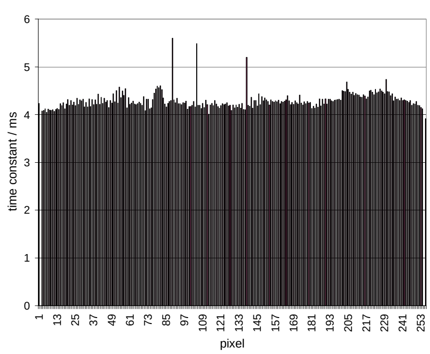



***Figure 4:*** *Detector pixel time constants.*

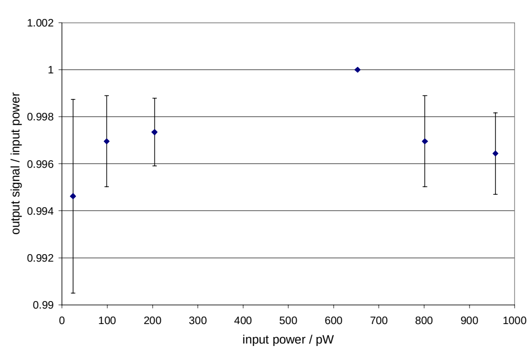



***Figure 5:*** *Average linearity of central 50 pixels.*

The pixel noise (NEP) distribution (for a 40 ms integration time) is plotted in figure 6. The average NEP is ~135 pW which is equivalent to ~2.6 codes of a single 1.098 ms ASIC reading. During evaluation of the ASIC a common fault was detected in that channel 64 of all devices exhibited high noise. To compensate for this the routing of detector pixels to ASIC input channels was arranged such that the two end pixels of the array were connected to channel 64 of an ASIC. This also meant that the end but-one pixels had to be left unconnected.

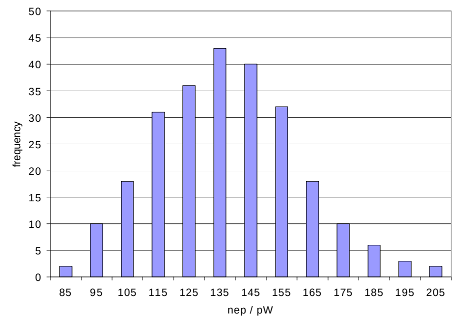



***Figure 6:*** *Pixel noise (NEP) distribution.*

The system spectral response was measured over the range from 0.3 µm to 25 µm and then extrapolated out to 50 µm using data obtained from reflectance measurements of a goldblack sample substrate. The results are shown in figure 7.

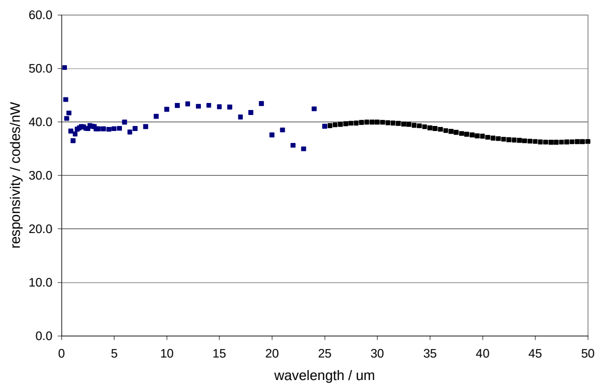



***Figure 7:*** *Absolute spectral response. (0.3 – 25 µm detector system, 25 – 50 µm goldblack sample).*

## FUTURE WORK

Three GERB instruments have been completed to date for launch on successive MSG satellites with a fourth in preparation. Together these instruments should provide continuous coverage of the Earth from geostationary orbit for a period of 15 – 20 years. For GERB-4 a new detector blacking program is underway with the construction of a new goldblack deposition facility at Leicester University.

## ACKNOWLEDGEMENTS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## REFERENCES


1. D.A. Bell: *A Geostationary Earth Radiation Budget Instrument*, Proc. SPIE 2209, 236, 1994.

2. N. Nelms, G. Butcher, C. Whitford, R.Cole, O.Blake, R. Williams, L. Nuttall: *Operation and performance of the ASIC for the GERB IR focal plane assembly*, Proc. SPIE 3759, 347, 1999.